Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: COUPP

Title: COUPP 60 kg Detector Water Veto Tank – Preliminary Design

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Reviewer(s):

Key Words: Water Tank, Coupp

Abstract Summary: Conceptual Design of the water tank needed to surround the 60 kg detector.

Applicable Codes: not applicable

Discussion:

A physics driven desire exists to surround the next COUPP detector with a water filled veto volume. Nominal dimension of this veto volume is a tank 10 feet tall by 8 to 10 feet in diameter. Existing five inch diameter phototubes mounted at the top of the vessel pointed down with the bases out of the water and the photocathode just immersed in the water. Therefore, the water tank needs to be opaque.

Plans call for installing the 60 kg COUPP detector in the Soudan II cavern. Geometry of the hoists servicing this location requires at least one dimension to be less than 38 inches.

Therefore, a one piece rigid water tank will not fit in the hoist. The tank must be assembled in the Soudan II cavern from segments that fit within the hoist,

Water temperature is desired to be uniform in a range between 15 C and 50 C. Thermal insulation (assumed to be polyurethane or polystyrene foam) will surround the tank to keep the heat load to the cavern at a minimum. For the initial design assumption, assume the radial thickness of the foam to be about 12 inches.

It is assumed that a flexible, one piece plastic liner is used to contain the water. Liner material will likely be polyvinyl chloride (PVC) or high density polyethylene (HDPE).

An electrically powered immersion heater entering the vessel from the top will used to heat the water to the desired temperature. Heating element will be located near the bottom of the vessel. Convection currents driven by the heated water rising should be sufficient to mix the water and achieve a near-uniform temperature without using circulation pumps.

Circumferential (hoop) stresses exerted on the water tank need to be restrained by a structural member. Nylon straps, Kevlar cloth, and sheet metal have all been evaluated. While inexpensive, the nylon straps require multiple straps adjacent to one and another at the bottom of the tank. It is not clear how one could tighten these straps so that the load was evenly distributed. Kevlar cloth has the advantage of very low stretch, but it would require the fabrication of a sewn cylinder to high dimensional tolerance. While possible, multiple tries may be needed to achieve the goal.

So, the suggested choice of material to take the hoop stress is to use a long, metal piano hinge attached to sheet metal. Hinge shown on the image has a hinge pin diameter of 5/8 inch. Metal thickness is ¼ inch and the knuckle length is 1 ½ inches. While not rated for a tensile load from the manufacture, calculations indicate that the hinge should be able to take approximately 500 pounds per inch and the maximum applied load is 208 pounds per inch. Shear on the 5/8 diameter pin is 312 pounds while it has an allowable shear of 1500 pounds.

Sheet metal needs only be approximately 1/16 of an inch thick to adequately take the hoop stress. Such thin metal does not need to be rolled to be shaped into the arc. Twelve gauge (0.1046 inch thickness) steel should be thin enough to easily form to the curved shape while thick enough to be easily welded to the ¼ inch think hinge material.

Each section of the inner vessel, when un-rolled, has an overall dimension of about 38 inches wide, 96 inches tall. Several sections (there are eight) should fit within the hoist easily. Insulation sections are (assuming 12 inches radial thickness) 48 inches wide, by 120 inches tall. Two sections should fit with the hoist cage at the same time.

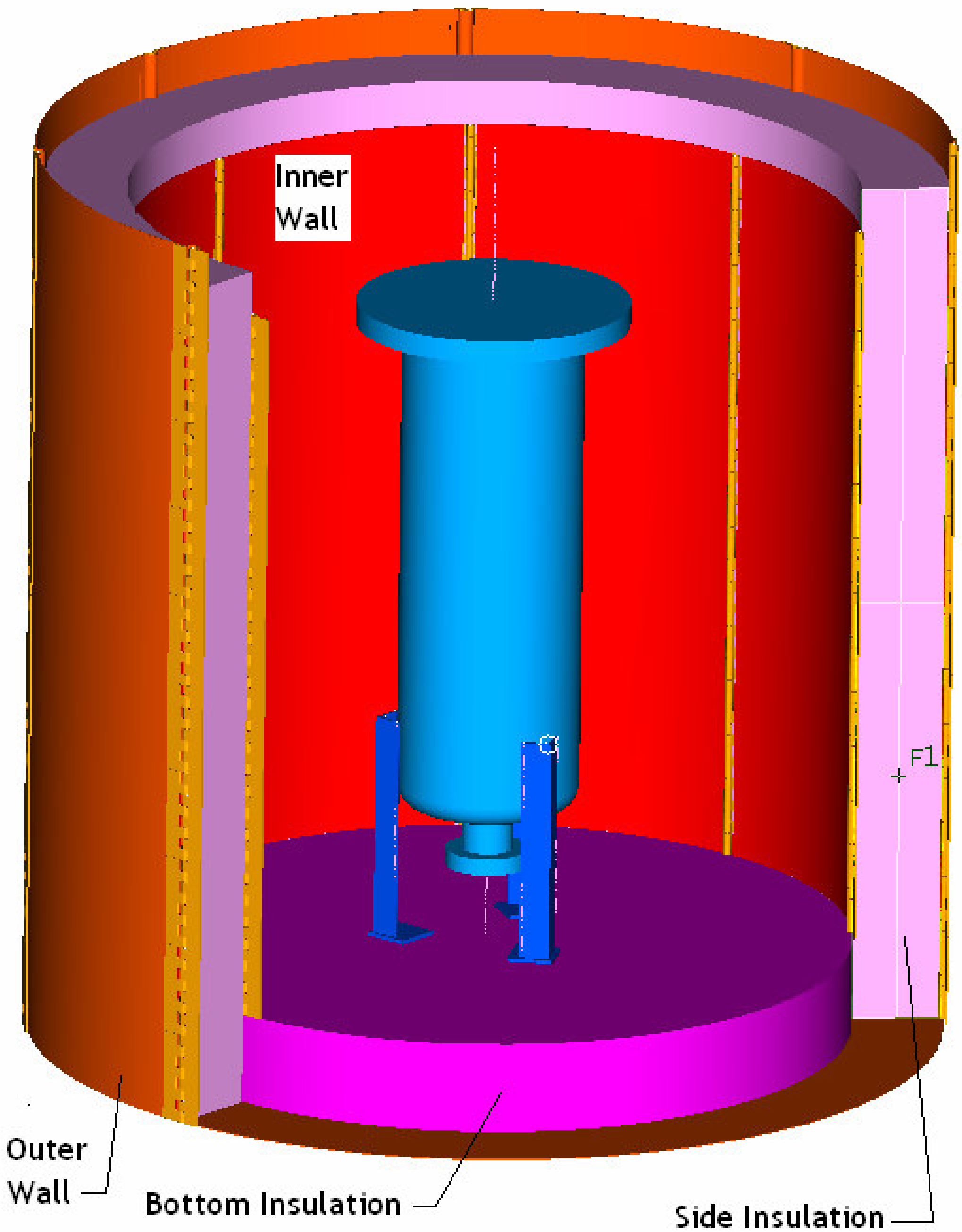
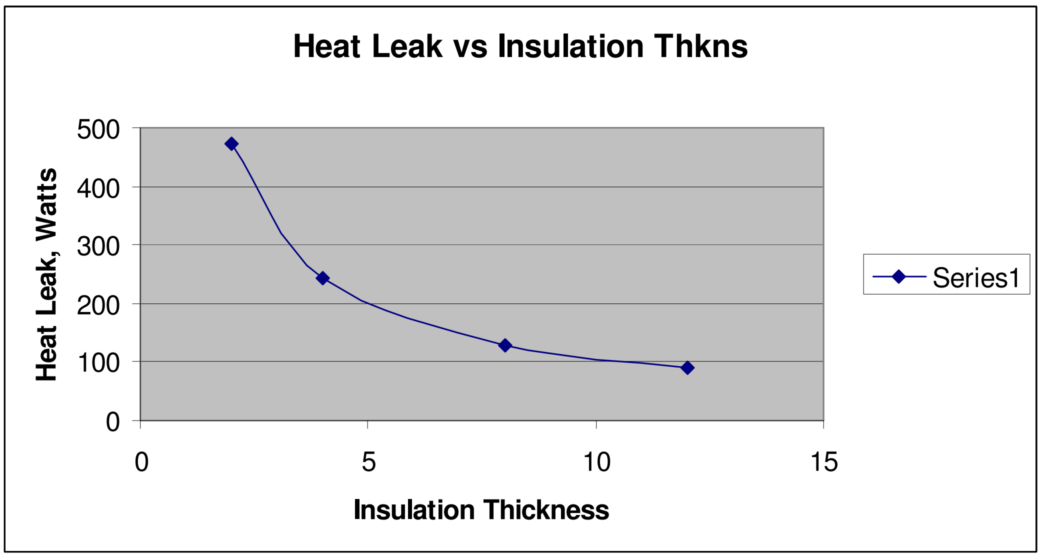


Image 1
Solid Model of the 60 kg Coupp Detector in an Eight foot diameter Water Tank and 12 inches of Radial Insulation

Simply for ease of modeling, the outer vessel wall is constructed using the same technique using sheet metal and piano hinges to generate a curved shell. The outer shell could be simplified to use less material and smaller piano hinges since the full hydrostatic load is taken by the inner shell. The outer shell is only present to protect the insulation from damage due to incidental contact.

Heat leak from the water tank to the room was estimated for four different thicknesses of insulation. Assuming that two part, rigid polyurethane insulation with a thermal conductivity of 0.026 W/m-K is used, and assuming that the thermal resistance due to the convection at the water surface and at the air surface is negligible, the total energy lost from the water to the air varied from a high of 470 watts to a low of 88 watts. Clearly, the thicker insulation reduces the heat load to the experimental hall to a level about equal to the heat load from a living human. This should be acceptable.



Graph 1
Insulation Thickness verses Heat Leak from Water Tank at 50 C

A finite element model of one half of a hinge knuckle was prepared to analyze the ability of a hinge to restrain the hoop stress. The result is shown in Image 2. This model takes one half of a hinge, restrains it at the far edge (to simulate a full length fillet weld attaching the hinge to the sheet metal) and applies a 200 pound load to the surface where the hinge pin would contact. The knuckle shown in this model is only ¾ inch long (actual hinge knuckle width is 1 ½ inches). Peak stress is approximately 15,000 psi (mild steel yields at 30,000 psi. Deflection is 0.0213 inches. Such a small deflection is acceptable in this application. Based on this analysis, the use of the hinge to join sections of the inner vessel sheet metal wall is satisfactory to restrain the hoop stresses.

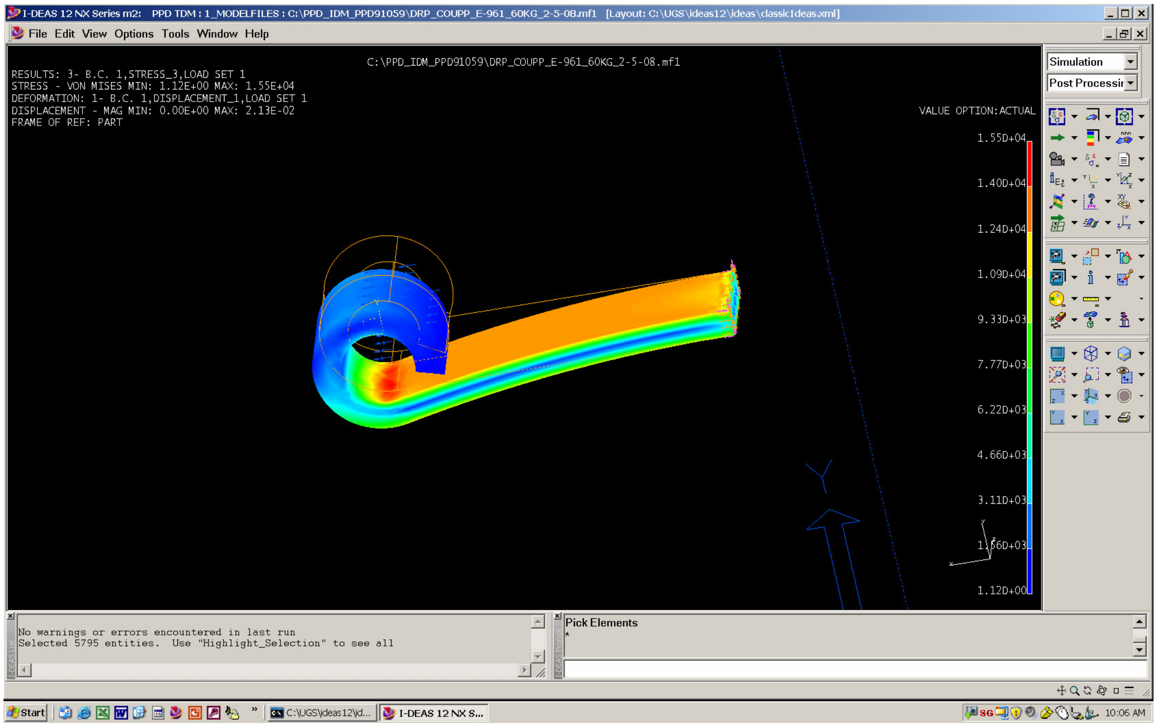


Image 2
Screen Capture of a FEA result of a 200 pound load
Applied to one half of a Hinge Knuckle